EC-2

AIRCRAFT for SPRAYING and DUSTING

BUREAU of ENTOMOLOGY and PLANT QUARANTINE
AGRICULTURAL RESEARCH ADMINISTRATION
U.S. DEPT. of AGRICULTURE

MARCH 1948

AIRCRAFT
FOR
SPRAYING AND DUSTING

Aircraft has attained an important position in insect-pest control in recent years. When properly equipped and operated for this purpose, airplanes are versatile and efficient, and have some marked advantages over ground equipment. Extensive outbreaks of insects or diseases may be treated rapidly without disturbing crops. Insecticides may be applied when the ground is too wet for the operation of ground equipment. Aircraft provides the only practical means of applying insecticides to great forest areas which cannot be reached with ground equipment. This is of particular importance.

Certain shortcomings should not be overlooked, however. It is more difficult to control the distribution of an insecticide when applied with a plane. Dusts or finely atomized sprays may drift to adjacent fields and cause damage. Small acreages usually can be treated more economically with ground equipment. Few farmers can justify owning a plane; so most of them must rely upon commercial operators for custom work if they elect to treat their crops in this manner.

Since the close of the war several prominent factors have served to encourage this means of controlling insect pests. There are now many qualified pilots and aircraft mechanics. Large numbers of used inexpensive airplanes, suitable for conversion to crop dusters and sprayers, have become available. Labor has been scarce and costly. The value of farm crops has been high enough to encourage custom dusting and spraying, even though it involves a substantial cash outlay to the grower. Newly developed insecticides have further stimulated interest in the commercial possibilities of this field.

In attempting to determine the most practical way to control some of the more economically important insect pests, the Bureau of Entomology and Plant Quarantine has developed, independently or in cooperation with other public agencies and individuals, various devices for dispersing insecticides with aircraft. The more practical installations have been tested extensively under field conditions. Some of them are briefly described herein.

Suspended Boom

Two mechanisms of the suspended-boom type have been developed in cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering. One is installed on an N2S (Stearman) biplane and the other on an L-4 Piper Cub. Both are equipped with pressure-type spraying systems.

The N2S airplane is used for dispersing solutions, suspensions, and emulsions. The essential parts of this equipment are a spray tank, a pump, and tubing booms for the attachment of nozzles.

The tank is of 70-gallon capacity and is installed in the front cockpit. An emergency dump valve with remote control to

the rear cockpit is installed in the tank outlet.

The pump is a 1½-by 1-inch centrifugal type, which permits the use of suspensions and emulsions, as well as solutions. It is suspended beneath the center of the fuselage, to the rear of the landing-gear assembly. It is wind-driven by a 4-bladed wood propeller 20 inches in diameter, mounted on the end of the pump shaft. The pitch of the propeller blades is 33½ degrees. A small brake drum with an external brake band is fitted on the pump shaft directly behind the driving propeller. A brake-control cable extends to the instrument panel in the rear cockpit.

The spray-control valve is of the quick-opening cam-action type. An adjustable hydraulic-pressure relief valve is connected to the pump discharge line between the pump and the spray-control valve. This relief valve is located so that the hand wheel for pressure adjustment is readily accessible to the pilot. The discharge from this valve is conducted back to the bottom of the tank to provide agitation, which is necessary when suspensions or emulsions are used. Submerging the outlet of the discharge line from the pressure-relief valve minimizes foaming of emulsions and suspensions.

A pressure gage is installed in the rear cockpit and connected by flexible copper tubing to the pump discharge line. The pump is fitted with a tachometer, with an indicating dial located in the rear cockpit.

The speed of the pump is approximately 3800 r.p.m., and it operates at a maximum pressure of about 30 p.s.i. (pounds per square inch). The maximum output at this pressure is 30 gallons per minute. With an output of 50 gallons per minute the pressure drops to 25 pounds. When the spray valve is closed, the spray liquid is by-passed through the pressure-relief valve for agitation. When the spray valve is open, only that portion of the pump output which is

not discharged through the nozzles is by-passed to the tank.

The spray boom is 1-inch steel tubing, mounted approximately 9 inches below the lower surface of the lower wings, midway between the front and rear spars. The boom extends from wing tip to wing tip and is provided with 84 nozzle outlets. When nozzles with a high discharge rate are used, only a portion of the outlets are fitted with nozzles and the other openings are plugged. Individual check valves are used at each nozzle to prevent loss of spray materials from the boom after the spray is cut off.

The installation on the L-4 Piper Cub airplane was developed for control of the European corn borer. Since it is a high-winged monoplane, the booms are set at

an angle with the ground. In other respects this installation is similar to the one described above, but because of the type of pump used it will not satisfactorily handle suspensions. It consists of a 28-gallon tank, a rotary-vane pump, and a spray boom equipped with nozzles. The tank is in the normal position of the rear seat. The pump has a capacity of 18 gallons per minute and develops a pressure of 50 p.s.i. It is clamped to the wing-lift struts on the left side of the fuselage and is directly driven by a 4-bladed, wood propeller 19 inches in diameter. Each side of the spray boom, which is of 3/4-inch thin-wall steel tubing, is 193 inches in length and is attached to the plane by four stays, three stays to the lift struts and one to clamps on wing spars

in the wing tip. Forty-five nozzle openings, spaced 4-21/64 inches on centers, are brazed to each boom. The nozzles, which face rearward, have a 1/16-inch orifice and are rated 0.22 gallon per minute at 50 p.s.i. pressure. The slope of the booms (from bottom of the fuselage to the wing tips) increases the safety of the installation by providing clearance should the plane wing over slightly in landing. Other elements in this installation are a pressure-regulating valve which can be adjusted by the pilot, a pressure gage on the instrument panel, and a quick-opening valve between the pump and the spray booms.

Tests made with this equipment indicate that, if the insecticide is to be evenly distributed over the entire swath, the amount of liquid released from the outboard ends of the spray booms should be somewhat greater than that released from the inboard ends. The airplane is operated at 4 to 10 feet above the ground at a speed of approximately 60 m.p.h. When it is equipped with 62 nozzles of the type described above (the other openings being plugged), the maximum effective swath appears to be about 56 feet, covering approximately 16 rows of corn.

A C-47 (Douglas) airplane has been equipped for the dispersal of DDT solutions in the control of gypsy moths. The installation consists of two 460-gallon aluminum, rubber-lined tanks, a pump, and underwing spray booms. Two-inch pipes conduct the insecticide from the tanks to quick-opening gate valves. Between the gate valves is a T leading into a 2-1/2-inch line, which leads to the pump. From the pump a 2-inch line carries the liquid to another T, which connects to two 1-1/2-inch aircraft aromatic-resistant hoses inside the center sections of the wings. The outer ends of these hose sections extend down through the lower surfaces of the wings, making connection to the spray booms. The tanks are placed one in front of the other, 42 inches apart, in the forward end of the fuselage. The pump, which is powered by a 9.2-hp., air-cooled gasoline engine connected directly to it, is placed in the after end

of the fuselage. The pump is a 2-inch centrifugal type with a capacity of 200 g.p.m. (gallons per minute). At a nozzle pressure of 25 p.s.i. its capacity is approximately 160 g.p.m. At 40 p.s.i. its capacity drops to approximately 120 g.p.m. The booms are of streamlined steel tubing of 2-inch nominal size. Each is approximately 24 feet long and extends from a point 17 feet from the center line of the fuselage outward to about 6-1/2 feet from the wing tips. They are suspended approximately 12 inches below the underwing surface one-third of the distance forward from the trailing edge of the wings. Each boom is equipped with 18 nozzle openings, some of which may be plugged in order to regulate the discharge rate of the insecticide. This airplane operates at a speed of approximately 150 m.p.h. about 150 feet above the forest canopy.

Numerous other modifications of the suspended-boom type of installation are in use. One of the simplest and least expensive of these has been constructed for control of the white-fringed beetle. It is principally used for insecticides in solution, but it is also suitable for any of the emulsions that do not require constant agitation. A 75-gallon tank is installed in the front cockpit of an N3N biplane, with a 2-inch outlet connected with a T to a 1-inch aluminum boom. Holes 7/32 inch in diameter, spaced 9 inches on centers, are drilled

along the entire boom length on the trailing side, slightly below center. A sheet-iron "breaker bar" is shaped around the upper back segment of the boom, approximately 3/8 inch from it. The leading edge of this bar is flared slightly upward and the trailing edge downward and backward. This flare gives a venturi action between the bar and the boom, which increases the velocity of the air that passes the outlets in the boom. This increase in velocity not only serves to increase the rate of flow of the insecticide but it also decreases the variation in the flow rate. When the liquid is released in flight, it emerges from the holes in the boom, impinges upon the lower edge of the breaker bar, and is released from the bar as a spray.

The principal advantage of this type of installation is that it is simply constructed with no moving parts. Its use consequently reduces repairs and operational delays to a minimum.

Since the installation has no pressure pump, constant pressure on the liquid insecticide is not maintained. Therefore, as the level of the liquid in the tank is lowered, the flow rate diminishes. This disadvantage, however, may be at least partially neutralized by the deceleration of the aircraft during the period of dispersal. Investigations are currently being conducted with modifications of this equipment which may provide greater uniformity in flow rate without the use of a pressure pump.

Wing-Tip Nozzle

The wing-tip-nozzle assembly was developed for gypsy moth control in 1945. The installation was made in an N3N biplane. It consists of a 90-gallon tank and aluminum tubing inside each lower wing to carry the insecticide solution from the tank through a pressure pump to twin nozzles mounted under the lower wings close to the wing tips. A sump at the bottom of the tank has a dump valve for the quick release of the

insecticide load in emergencies. The pump is of a gear type, equipped with a braking device, which is mounted on the under side of the fuselage along the center line of the aircraft. It is powered with a 6-bladed propeller, which rotates at approximately 2700 r.p.m. and develops a pump pressure of 140 p.s.i. when the aircraft is traveling at an air speed of 80 miles per hour.

Each wing-tip-nozzle assembly consists of tubing which runs from the feeder line within the wing downward about 18 inches to a section of cross tubing about 12 inches long. One nozzle is fitted to each end of this cross tubing and directed at an angle of 45 degrees forward, downward, and outward.

Self-closing electric-solenoid valves are mounted directly behind the twin nozzles to eliminate drooling when the flow of liquid is cut off at the end of each flight strip. These electric valves are controlled by a pistol-grip trigger mounted on the end of the control stick, so that it is unnecessary for the pilot to remove his hand from the throttle when actuating the valves. When the valves are closed, the liquid insecticide flows through the relief valve into the bottom of the tank providing some agitation to the concentrate within it.

Flat spray nozzles, which allow a total discharge of approximately 20 gallons of insecticide solution per minute, are used. The output can be readily varied by using nozzles with a larger or smaller orifice and adjusting the pressure to obtain the desired atomization of the liquid.

The wing-tip-nozzle design, although perhaps not so effective as the suspended-boom type for treating field crops, has the advantage of being less expensive and producing less drag on the aircraft. However. since a gear-type pump is employed to develop required pressure for this installation, its use is restricted to liquid insecticides that contain no abrasives or suspended solids.

Although the installation described above takes significant advantage of the wing-tip vortex to achieve a wide swath and satisfactory distribution of insecticide for forest work, a twin-nozzle device similar to that used at the wing tips has recently been added to the installation. attached to the under side of the fuselage at the tail. These additional nozzles give a more even distribution of insecticide and are particularly important for low-flying applications to field crops. With this arrangement the discharge rate from the various nozzles is adjusted so that the amount emitted from the tail-nozzle assembly is less than that released by either wing-tip-nozzle assembly.

Spinner Disk

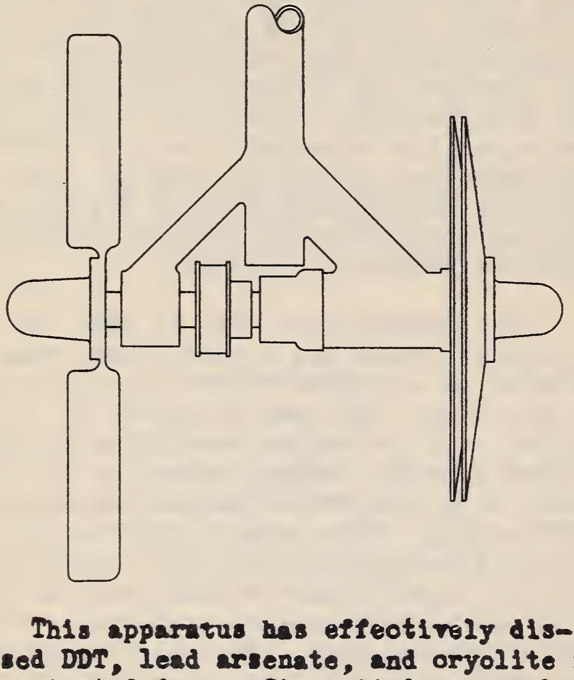
The spinner-disk assembly provides a means of dispersing heavy suspensions and emulsions which may have abrasive or other characteristics that prevent their use in any type of spray-nozzle assembly. It was first installed on a fixed-wing airplane in 1944 and used in spraying forest areas for gypsy moth control. It consists of a 110-gallon aluminum tank mounted in the front cockpit of a White Standard biplane; a 2-inch pipe line extending from the tank outlet to the center of a 2-inch cross boom

which is attached to the lower longerons at the rear of the pilot's cockpit; an insecticide-distributing assembly mounted at each end of the cross boom; and gages and operational controls mounted in the rear cockpit, readily accessible to the pilot.

On the forward end of each insecticide-distributing assembly is mounted a 6-bladed fan connected by a steel shaft about 18 inches in length to two 14-inch-diameter, concave steel disks spaced 1/8 inch apart, mounted at the rear of the assembly. (See diagram on opposite page.) Power to rotate the insecticide-dispersing units (located outside of the slip stream, 6 feet from the fuselage) is derived from the forward motion of the aircraft. Both units are equipped with brakes so constructed that they can be operated by a single lever mounted in the pilot's cockpit.

When the airplane is flying at approximately 80 m.p.h., these dispersing units rotate at about 2500 r.p.m. The insecticide flows by gravity from the tank, through the connecting pipe line and cross boom, to

the rear bearing housing of the distributing unit, into a 2-5/8-inch diameter cavity in the center of the disks. It then flows onto and spreads thinly over the concave surfaces of the disks. By centrifugal force it is thrown or sprayed into the surrounding air from the peripheries of the disks. The air blast resulting from the forward movement of the aircraft further breaks up the liquid insecticide that has thus been released. Valves controlling the rate of flow of the insecticide are located in the distributing heads close to the spinner-disk assembly, where they prevent drooling when the flow of liquid is cut off.



This apparatus has effectively dispersed DDT, lead arsenate, and cryolite in concentrated form. Since it does not depend on pressure pumps or nozzles, it can be used for almost any liquid that will readily flow by gravity. It is a relatively expensive installation, however, because of the special machining required in the construction of the high-speed dispersing units. Another disadvantage is that, because constant pressure on the insecticide is not maintained, the flow rate is not uniform. For the dispersal of insecticides now most commonly used, therefore, other types of mechanisms perhaps have greater merit.

Suspended Tank

In mosquito-control research two N2S (Stearman)biplanes are being employed. Each is equipped with a 75-gallon auxiliary jettisonable fuel tank suspended from a bomb shackle beneath the fuselage. These tanks are standard Army Air Corps items. One, used for the dispersal of liquid insecticides, has underwing spray booms fitted to it. The other has been reconstructed to provide for the dispersal of dust.

These installations have the following advantages: The front cockpit is left free for an observer (but not in conjunction with a full insecticide load), the tank can be quickly attached or detached from the plane and other tank units substituted for the dispersal of different insecticides. The disadvantages, especially from a control-operation standpoint, are as follows: The tanks are of limited capacity, they create a considerable drag on the aircraft, and the aircraft engine must be cut out when the tanks are refilled.

The installation that is used for applying liquids has a centrifugal pump mounted on a special bracket on the front of the tank. The pump is driven by a propeller, and its output is carried through 1-inch aircraft tubing, curved to fit the tank, to a 3-way valve mounted on the side of the tank. This valve, which is controlled from the cockpit, directs the liquid either into the spray booms or back into the tank, thus providing necessary agitation for materials in suspension. The spray booms are suspended from the lower wings of the airplane. The arrangement of nozzles attached to the spray booms may be varied to provide a delivery rate of 5 to 14 gallons per minute.

For use in spreading dust the tank was converted by cutting away the bottom two-thirds of the tank and making new sides and a bottom from 0.035-inch sheet metal. Obstructing bulkheads were removed, except the rear one, which was completely sealed to block off the rear portion of the tank.

Steel tubing, 1/2-inch square, was welded around the edge of the upper portion of the tank as a frame and reinforcement. The new portion of the hopper was bolted to this frame.

A gate for releasing the dust was made by cutting 14 crosswise slots, 1 by 4-3/4 inches, in the new tank bottom. Matching slots were cut in a sliding door, which was made of 0.035-inch sheet aluminum. This door was fitted into a channel that runs the length of the tank, and can be opened or closed by means of a lever in the cockpit. An agitator 53 inches long, with four 1/16-inch wire blades set to form a circle 4-1/2 inches in diameter, was mounted above the gate by a bearing at the front and rear ends. The agitator is turned by a wind-driven wooden propeller mounted on the front of the tank.

The installations described above are experimental mechanisms, and in their present form are of limited value in control operations.

Spreader

Although the discovery of new highly toxic insecticides has led research agencies to emphasize the development of machinery for dispersing liquids, satisfactory equipment has also been designed for the aerial application of dusts and baits. One such device, developed by the Tennessee Valley Authority for use with dust in the control of mosquitoes, is installed in a 4-DX (Stearman)biplane. It consists of a hopper, venturi, agitators, and a valve. A 24-cubic-foot plywood hopper is installed in the front cockpit. The interior corners are packed with a sealing compound and covered with a doped linen strip. A 3-inch piano-wire agitator of open-drum type is located in the throat of the hopper and a 6-inch-diameter agitator of the same type above it. A 4-bladed wooden propeller and reduction gear located on the leading edge of the lower wing drives the upper agita-

tor. The lower agitator is operated by a sprocket and chain placed between the hopper and the fuselage covering. The ratio of the propeller speed to the agitator speed is 50 to 1.

An aluminum sliding gate valve controls the dust feed. It is operated by a hand lever in the left side of the cockpit.

The venturi is actually a half-venturi. It is 30 inches wide and has plywood side walls. The major constriction is accomplished by a sheet-aluminum bottom panel which is built up into an airfoil section having a 43-inch chord very similar in appearance to an airplane wing section. The maximum depth of the venturi is 8 inches, and the depth at the point of maximum constriction is 3 inches. This point is directly beneath the valve opening. The venturi is fastened against the bottom of the fuselage, which serves as the top of the venturi structure.

The hopper in this installation was built of wood because of the structural failures caused by vibration in metal hoppers. It has been found, however, that certain metals, such as 24 ST aluminum, reinforced with light metal angles, are satisfactory for this purpose. For moist baits it is especially desirable to use a metal hopper. It is difficult to waterproof wood

satisfactorily.

Bait may be spread with equipment similar to that described above. Some changes are necessary, however. Others are desirable. For moist bait, and especially for sticky bait, it is important to provide a sturdier lower agitator, one that will churn the bait and feed it uniformly through the full width of the hopper throat. Bait, being less fluid than dust, requires slower as well as more powerful agitation. Both these requirements can be met by placing suitable reduction gears in the driveshaft between the wind-driven propeller and the agitators.

For spreading bait the venturi described above is not the most efficient device. It creates a suction at the hopper throat, which is desirable, but it does not broaden the swath. An outward horizontal thrust is needed for this purpose and is usually obtained in practice in one of two ways—(1) by making the venturi fan-shaped at the outlet end, with baffles in it to force the bait outward to the sides, or (2) by dividing the tail section of the venturi and spreading it to form two separate outlet passages, through which the bait is thrust outward to the sides.

The slope of hopper walls should not ordinarily be less than 55 degrees to the horizontal. This appears to be the minimum slope that will allow a positive flow of standard materials.

Canadian Bait Hopper

The Canadian Department of Agriculture, in cooperation with the Department of Defence, has recently developed, at the Suffield Experiment Station, an experimental device for the dispersal of bait which is worthy of note. It is installed in a C-47 (Douglas) airplane and is particularly significant in that no agitators are employed. The hopper holds approximately 1400 pounds of oil bait. The throat extends down through the floor of the fuselage and is cut off at an angle of approximately 30

degrees with the horizontal. The top of the hopper has a tight, fixed cover. Bait is introduced through hinged self-closing doors in the side walls of the hopper, near the top. The sides of the hopper are perforated with narrow horizontal slits. In flight, when the gate valve in the throat is opened, the rush of air past the throat opening induces a vacuum within the hopper. The vacuum is relieved by the passage of air. from within the fuselage, through the slits in the hopper walls, into the hopper. This flow of air forces the bait lying next to the hopper walls down through the throat, preventing it from adhering to the walls or bridging over the throat.

Exhaust Generator

An exhaust generator for dispersing insecticide solutions for the control of mosquitoes is currently being tested on a N2S (Stearman) biplane. It consists of an extension to the exhaust pipe, leading backward from the engine on the starboard side of the fuselage to a point about 6 feet behind the rear cockpit. Close to the end of this extension is a venturi constriction, into which the spray solution is injected. The rapid flow of the hot exhaust gases at the point of constriction atomizes the solution into fine droplets. A portion of the solvent volatilizes, and the insecticide is discharged as a combination mist and smoke.

Although this equipment emits exceedingly small droplets, many of which penetrate heavy vegetative cover, there appears to be some loss of material through volatilization and carbonization, and there is a considerable loss through the failure of the smaller droplets to reach the target area.

Military Developments

During the recent war the Navy and War Departments were engaged in research on the

use of high-speed aircraft in insect control. Although their primary interest was in mosquitoes the mechanisms that were developed may be adapted for use in controlling many other insect pest.

One of the most effective devices is an assembly that can be quickly installed in a cargo-carrying C-47 aircraft. Two or three 350-gallon emergency droppable bomb-bay tanks with a combined capacity of 700 to 1,000 gallons are installed on fabricated cradles in the anterior part of the plane. The bottoms of the foremost tanks are 16 inches, and that of the posterior tank 14 inches from the floor. The entire installation is tied to the floor by means of steel cables.

These tanks can be filled in 10 minutes through a 2-inch piping system extending through ports in both sides of the fuselage. By the force of gravity they empty into a smaller tank equipped with a float valve. This valve maintains a constant head and therefore a fairly constant pressure within the small tank, thus assuring an even flow of the insecticide through the discharge pipe. A rotary valve is installed immediately below the constant-head tank. This valve is activated by the parachute release cable in the copilot's seat, and remains closed by a spring action. The discharge pipe is about 3 inches in diameter and extends about 3 feet below the belly of the fuselage through an inspection plate to a point outside the slip stream. Discharging into a cylindrical venturi, the insecticide stream is broken up into fine spray particles.

Another device for discharging liquid insecticides consists of a grid suspended beneath the fuselage. This grid is made up of a 2-1/2- by 6-inch streamlined pipe extending downward from the tanks through the belly of the fuselage. For a distance of 24 inches on each side of this pipe there are six horizontal streamlined tubes spaced 2-1/8 inches on centers. These tubes are perforated along the top and bottom sides with 1/25- by 2-inch slots 3 inches on cen-

ters. The ends of these tubes are welded to plates which extend upward and are fastened to the sides of the fuselage. This device gives satisfactory results, but available evidence indicates that it is not significantly superior to the straight-line discharge pipe. In installations that do not provide for maintaining a constant head, however, this device may have an advantage worth noting. The negative pressure developed by the venturi action between the horizontal grid tubes is said to decrease the variation in the flow rate below that which could be expected from gravity alone.

Rotary-Wing Aircraft

For a number of years rotary-wing aircraft has been used for the dispersal of insecticides, but it is still difficult to make a practical evaluation of such craft in relation to fixed-wing planes. The helicopter, which is replacing the autogiro, appears to give much promise. Its high initial cost, however, compared with the low cost of standard airplanes now available through surplus-property channels, places it at a disadvantage and retards its development in this field. Although its efficiency in large-scale operations is not established at the present time, it seems to have unquestionable merit for the treatment of small fields, especially those remote from landing strips.

General Considerations

An understanding of the Civil Air Regulations is important in making a selection of mechanisms for dispersing insecticides from aircraft, and in the actual operation of them. These regulations insure that aircraft used for insect control shall be airworthy and suitable for the type of work to be done and that the installation of the dispersal equipment shall not weaken the structure of the aircraft or destroy its balance. Information regarding them may be obtained from any office of the Civil Aero-

nautics Administration, which is also in a position to advise on the subject of licenses, waivers, etc.

In addition to the selection of efficient mechanisms for aircraft in insect-pest control, attention should be given to several other aspects of the operational problem. The geography of the area to be treated, the characteristics of the insect to be controlled, and the nature of the insecticide to be used all affect the efficiency of the work.

Certain insects are more readily controlled by treatment of the soil. Some, which do not move about, can be controlled only when the insecticide is applied directly upon them. The control of certain ambulatory insects requires only that the insecticide be deposited in the general area of their activity.

The scope of these typical problems suggests the need for exercising expert judgment in selecting insecticides and devices for applying them. Equipment may be required to spread bait materials that are dry, moist, or perhaps sticky; dusts with cohesive or inflammable properties; abrasive or corrosive suspensions; emulsions with collodial characteristics; or solutions that may contain chemicals capable of decomposing equipment.

In selecting the most practicable and efficient type of aircraft for work of this character, one should give consideration to the size of the fields to be treated, their proximity to landing strips, the loads to be carried, the elevation and type of terrain to be traversed, the cost of operation and maintenance, and the adaptability of the aircraft to the installation of dispersal mechanisms. Two of the more important attributes in aircraft used for this purpose are (1) an ability to take off and land on a strip of minimum length, and (2) a specification in which the ratio of pay load to total weight is high.

For efficiency in aircraft work it is essential to minimize and expedite repairs and the replacement of parts. Pumps that are suitable for the particular liquid to be sprayed should be selected. Nozzles should have a minimum of constricted passages and they should be readily replaceable as they may become worn through abrasive action. Booms should have removable plugs at the ends and T's and Y's at points of directional change, so that they can be swabbed out when they become congested or when a change is to be made in spray material.

Experiments are currently being conducted with devices for releasing liquid from different points under the wings and fuselage. These devices range from a single emission pipe protruding from the bottom of the fuselage to spray booms that project beyond the wing tips. Although the latter type of installation probably takes full advantage of the wing-tip vortex, it cannot yet be definitely stated that it is superior under all conditions to some of the other types.

Swath width is directly affected by the height of the aircraft above the crop being treated and by the velocity of the cross-wind component. Since these factors are often variable, especially over rough terrain, swath width cannot always be accurately predetermined.

In the use of liquid insecticides the size and uniformity of spray particles is significant. For some purposes sprays of small particle size have definite advantages, but even slight wind currents may keep them from reaching the crops or insects being treated or carry them outside the field upon which coverage is desired. There is the additional disadvantage that very small droplets may not impinge upon plant or insect surfaces or that they may evaporate before reaching their target. Large droplets are much more easily controlled, but they may be wasteful of materials, burn or otherwise injure foliage, or not give uniform or complete coverage.

Droplet size of insecticidal sprays is influenced by several factors. In general, average droplet size is increased by (1) increase in the viscosity of the liquid, (2) decrease in the air speed of the aircraft, and (3) decrease in the mechanical break-up of the liquid at the point of discharge. A variation of any one of these factors will affect the size of the droplets released in the air. No general formula can be given for determining droplet size because of the numerous variables present. Each type of aircraft and each type of dispersal mechanism must be given actual field tests. For this reason it is desirable, in planning equipment for general use, to allow for some flexibility by providing for the convenient adjustment of the number and size of discharge outlets.